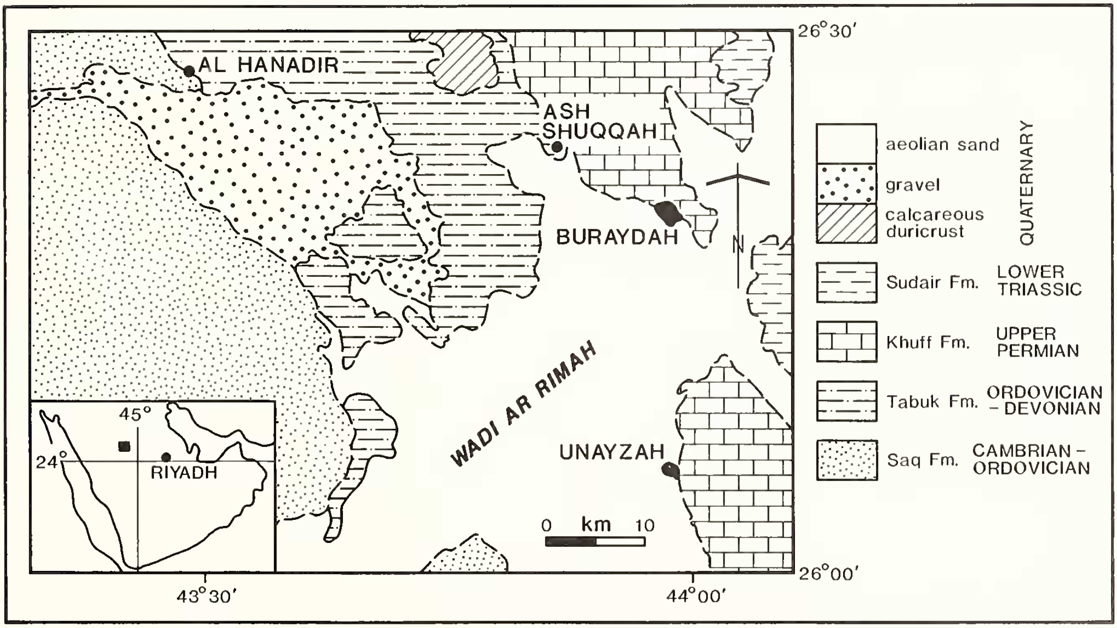
LOWER ORDOVICIAN TRILOBITES FROM THE HANADIR SHALE OF SAUDI ARABIA

by A. A. EL-KHAYAL *and* M. ROMANO

ABSTRACT: Recent collections from the Hanadir Shale (Llanvirn) include a more diverse trilobite fauna than was originally known. In addition to the previously described *Plaesiaconia vacuvertis* and *Neseuretus* (*Neseuretus*) *tristani* the following have been recognized: *N.* (*N.*) cf. *tristani*, *P.* sp. aff. *P. rara*, *Kerfornella* sp., *Kloucekia* sp., *Ningkianolithus hanadirensis* sp. nov., and asaphid indet. The fauna also includes graptolites, brachiopods, bivalves, ostracods, and orthocones. The trilobites confirm the 'Gondwanan' aspect of the fauna.

THIS paper presents a record of Lower Ordovician trilobites from the Hanadir Shale (Member) of the Tabuk Formation, Saudi Arabia. The trilobites were collected by one of us (A.A. El-K.) at Al Hanadir (26° 27′ 50″ N., 43° 27′ 20″ E.) about 53 km west-north-west of Buraydah, Al Qasĭm Province (text-fig. 1). Thomas (1977) had earlier described and figured *Plaesiaconia vacuvertis* Thomas from the type locality (erroneously quoted by Thomas as 25° 28′ 00″ N.) and recently Fortey and Morris (1982) figured *Neseuretus* (*Neseuretus*) *tristani* (Desmarest, 1817) from the Hanadir Shale further north. No other trilobites have been recorded or figured from this unit and so the recently discovered material is of interest.



TEXT-FIG. 1. Geological map of Al Qasĭm Province, Saudi Arabia, showing location of Al Hanadir section (see text-fig. 2). From Bramkamp *et al.* 1963.

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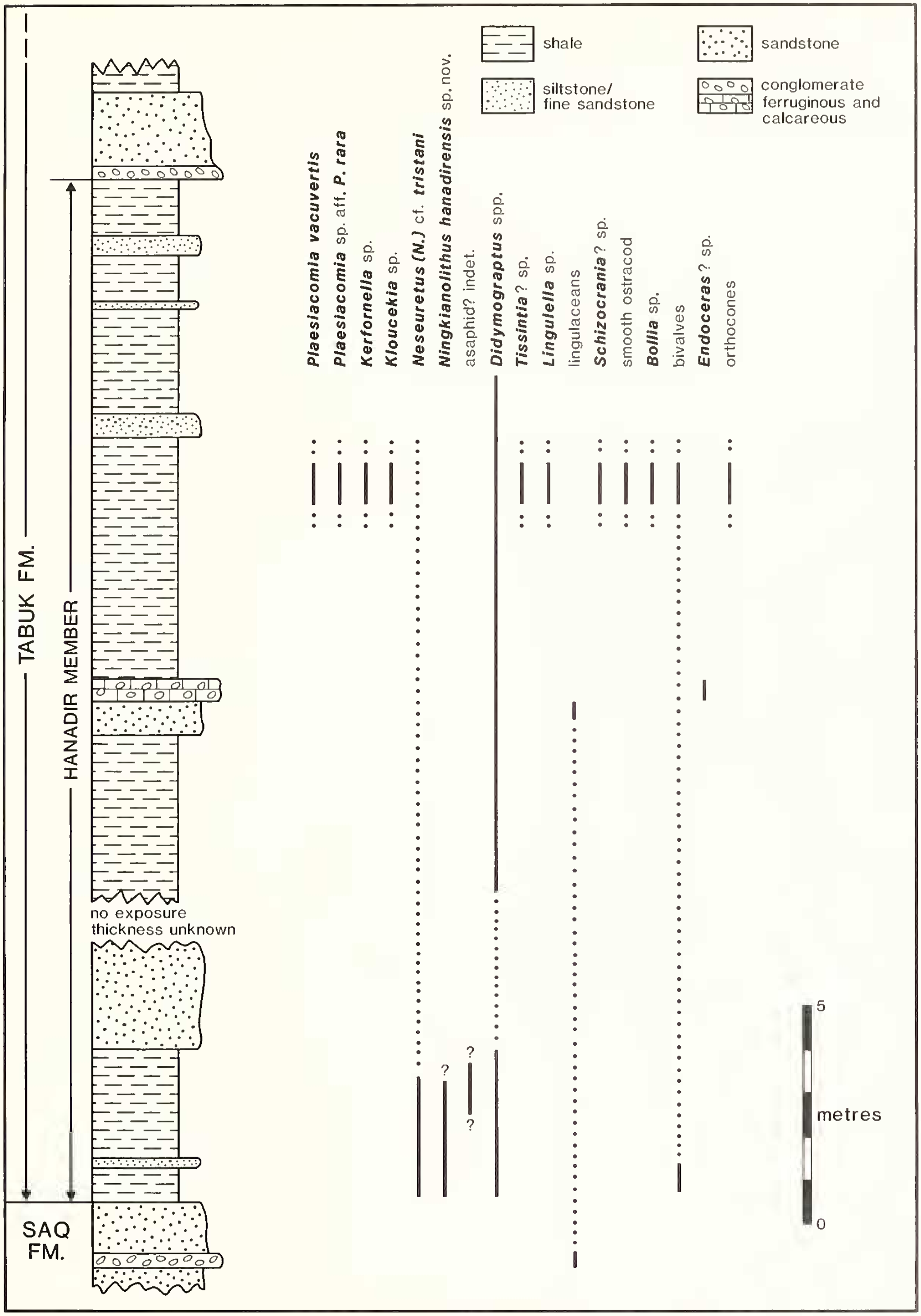
The lithostratigraphy of the Tabuk Formation has been described by Thralls and Hasson (1956), Steineke *et al.* (1958), Helal (1964, 1968), Powers *et al.* (1966), and McClure (1978). According to Powers *et al.* (1966) the Tabuk Formation (lower Ordovician to lower Devonian) rests conformably but with a sharp contact on the sandstones of the Saq Formation which is of possible Cambrian to lower Ordovician age. Helal (1964), however, regarded the contact as being disconformable. We prefer to follow Powers *et al.* (1966), although it is recognized that at present there is no strong faunal evidence. The top few metres of the Saq Formation consist of medium-grained, cross-bedded, sandstones with ripple marks up to 20 cm in wavelength. Approximately 1·5 m below the base of the Hanadir Member (text-fig. 2) is a thin (20 cm) conglomerate with sandstone pebbles up to 30 cm across and containing disarticulated and broken valves of lingulacean brachiopods in the matrix. This bed is overlain by fine-grained sandstones with *Cruziana* and bundles of traces resembling *Arthrophycus*. The presence of *C.* cf. *furcifera*, *C. huberi* (see Powers *et al.* 1966) and *C. goldfussi* (see Helal 1968) suggests a possible Arenig age for this part of the unit. The association of lithofacies and trace fossils resembles the lower Ordovician pebbly channel-sand facies of Jordan, described by Selley (1970). Beds containing lingulacean debris are found at a similar horizon in central Portugal and Brittany where they occur at the top of the Armorican Quartzite. The Hanadir Shale forms the basal member of the Tabuk Formation and varies in thickness from 12·2 to 68·5 m (Powers *et al.* 1966, pp. D112–113). At Al Hanadir it is at least 23 m thick; this is based on the 2 m thick sandstone bed shown in text-figure 2 as representing the base of the overlying sandstone unit (unit 2 of Powers *et al.* 1966). There is a gap in the exposure, however, in the lower part of the sequence. The Hanadir Member consists mainly of pale buff to greenish-brown shale, occasionally gypsiferous and limonitic, with thin beds of siltstone, fine sandstone, and ferruginous, calcareous conglomerate. The 2 m thick sandstone bed overlying the Hanadir Member has a conglomeratic base with abundant brachiopod debris dominated by lingulaceans.

Graptolites from the Hanadir Shale have been known since 1947 (see Powers *et al.* 1966, p. D25) and were later identified by R. J. Ross, Jr. as *Didymograptus protobifidus* Elles. McClure (1978) regarded the graptolites from the shale as indicating an upper Llanvirn, *murchisoni* Biozone age and stated (p. 324) that '. . . Trilobites and a rich chitinozoan and acritarch assemblage substantiated this age assignment'. On the basis of previous graptolite determinations, Dean (1980, p. 8 and table) considered the Hanadir Shale to range in age from upper Arenig to top Llanvirn. Khashogji (1979) concluded that the *murchisoni* Biozone was indicated for assemblages occurring 1·5–2·0 m above the base. The most recent reference to the graptolite fauna was by Fortey and Morris (1982, p. 68) who listed *D. murchisoni*, *D.* cf. *geminus*, *D. artus*, and *D.* cf. *spinulosus* and concluded that an upper Llanvirn age is likely. Fortey and Morris figured *N.* (*N.*) *tristani* from within the graptolitic sequence and recorded associated inarticulate brachiopods (*Schizocrania*?, *Monobolina*, *Lingulella*) as well as the bivalve *Glyptarca* cf. *narajoana* (Verneuil and Barrande).The assemblage from the Hanadir Shale indicates that the unit contains a more diverse trilobite fauna than was originally thought and provides additional information on the affinities and provincialism of the fauna.

AGE OF THE TRILOBITE FAUNAS

In the shales immediately overlying the sandstones of the Saq Formation there occurs a restricted assemblage of trilobites (*Ningkianolithus hanadirensis* sp. nov., *Neseuretus* (*Neseuretus*) cf. *tristani*, and an indeterminate asaphid) associated with rare pendent graptolite fragments and bivalves. *Ningkianolithus* occurs in the Shirgesht Formation of Iran, where it is associated with other trilobites indicating 'both Lower and Middle Ordovician horizons' (Dean 1980, p. 18; Ruttner *et al.* 1968, pp. 35–36). In China, where it occurs with abundant *Neseuretus* (Lu 1975; Sheng 1980, table 4), *Ningkianolithus* is known from the Dawan and Meitan Formations of upper Arenig age. *Neseuretus* (*N.*) *tristani* is not recorded from beds of Arenig age and Fortey and Morris (1982) regarded the species as being a typical Llanvirn form which 'extended over much of Gondwanaland'. Hammann (1983, p. 57), however, considered the species to be of Llandeilo age in Spain, the subspecies *tristani tristani* being restricted to the lower Llandeilo. The older Iberian species, *N.* (*N.*) *leonensis* and



TEXT-FIG. 2. Simplified geological section through the Hanadir Member at Al Hanadir (26° 27′ 50″ N., 43° 27′ 20″ E.).

N. (*N.*) *avus* are of Arenig to ?lower Llanvirn, and Llanvirn age respectively (Hammann 1983, pp. 58–63). Thus the age of the *Ningkianolithus–Neseuretus* (*Neseuretus*) association in Saudi Arabia remains unproven for the present. Although the genus *Ningkianolithus* is apparently restricted to rocks of Arenig age the presence of *Neseuretus* (*N.*) cf. *tristani*, together with the indeterminate pendent graptolites, suggests that the assemblage is younger. We consider a lower Llanvirn age to be most likely for the lowest beds of the Hanadir Shale.

A more diverse assemblage (with five trilobite species, brachiopods, bivalves, graptolites, and ostracods) occurs a further 10 m or so higher up the sequence (text-fig. 2). A gap in the section near the base of the Hanadir Shale precludes a more accurate determination of the vertical separation. This assemblage is of upper Llanvirn age as deduced from the graptolites (see earlier); the trilobites are as yet inconclusive. *N.* (*N.*) *tristani* ranges in age from Llanvirn to Llandeilo elsewhere (see above); *Plaesiacomia vacuvertis* is known only from the Hanadir Shale while *P. rara* is of Caradoc age in Bohemia and *P.* cf. *rara* and *P.* n. sp. aff. *rara* (Henry 1980) are of Llandeilo and Caradoc age respectively in north-western France. *Kerfornella* has been recorded from the Llanvirn at Crozon and Normandy (Henry 1976, 1980) and the present record extends the known geographical range of the genus. The incomplete specimens of *Kloucekia* sp. do not allow any close comparisons to be made. Also at this level are inarticulate brachiopods and *Tissintia*? sp. (the latter being few and fragmentary) and at least two species of ostracods, one being a smooth and elongate form, the other provisionally referred to *Bollia*.

AFFINITIES OF THE TRILOBITE FAUNAS

In the light of the recent paper by Fortey and Morris (1982) some comments may be made on the distribution and significance of the faunas. The Saudi Arabian assemblages contain elements known from widely separated areas within 'Gondwanaland' as understood by Cocks and Fortey (1982) and Fortey and Morris (1982). For example, *Ningkianolithus* and *Neseuretus* are common in the lower Ordovician of China while *Plaesiacomia*, *Kerfornella*, *Kloucekia*, and *Neseuretus* are typical genera of this age in western Europe and North Africa. Thus the Arabian faunas show mixing of east and west elements and indicate the general uniformity of conditions and an absence of any major barrier to dispersion along the shallow, shelf seas of that palaeocontinent. We are, therefore, in agreement with Fortey and Morris that southern Europe was not separated from North Africa by a 'Proto-Tethys' (Whittington and Hughes 1972) ocean during the Lower Ordovician.

THE ASSOCIATION OF *NESEURETUS* AND *PLAESIACOMIA*

Fortey and Morris regarded the association of *Neseuretus* with the inarticulate brachiopods *Schizocrania*?, *Monobolina*, and *Lingulella*, and bivalve *Glyptarca* cf. *narajoana* as an inshore, low diversity fauna from clastic facies. They also mentioned *Plaesiacomia* as showing a restricted, boreal distribution in the lower Ordovician (Dean 1976) but argued that it is generally found in deeper water facies than *Neseuretus*. The distribution of *Plaesiacomia* during the lower Ordovician parallels that of *Neseuretus*, although showing a more restricted range, and the suggestion that *Plaesiacomia* is a 'deeper water' genus is difficult to substantiate from what is known of assemblages from Iberia and Brittany. *Plaesiacomia* and *Neseuretus* are now known to coexist in the following areas: Brittany and Normandy (Henry 1980); Spain (Hammann and Henry 1978; Hammann *et al.* 1982; Hammann 1983), Portugal (Cooper 1980; Romano 1982; Hammann *et al.* 1982), Morocco (Destombes 1976), and Saudi Arabia. Although Fortey and Morris stated that the *Neseuretus* fauna (*Neseuretus* community type of Fortey and Owens 1978) is characteristic of a clastic facies, the same may be said for *Plaesiacomia* since it too occurs in a range of lithotypes from fine siltstones ('shales') to sandstones. Thus it is difficult to envisage a 'deeper water facies' for *Plaesiacomia* based solely on distribution and associated rock type, and although the present authors would not disagree that the presence of the *Neseuretus* fauna indicates a former inshore facies fringing Gondwanaland, a similar argument may be applied to *Plaesiacomia*. There is as yet no strong evidence to suggest that *Neseuretus* is the shallower water form of the two.

SYSTEMATIC PALAEONTOLOGY

The stratigraphic horizons given below are in most cases measured from the top of the Hanadir Shale, i.e. the base of the 2 m thick sandstone bed mentioned above. This is because at present there is an unknown thickness of shale towards the base of the unit. Specimen number prefixes It and H refer to British Museum (Natural History) and Geology Department, King Saud University, Riyadh, respectively.

Family CALYMENIDAE Burmeister, 1843
Subfamily REEDOCALYMENINAE Hupé, 1955
Genus NESEURETUS Hicks, 1873
Subgenus NESEURETUS (NESEURETUS) Hicks, 1873

Type species. *Calymene parvifrons* var. *murchisoni* Salter, 1865 (see Whittard 1955, p. 139; Fortey and Morris 1982, p. 69).

Neseuretus (*Neseuretus*) *tristani* (Brongniart *in* Desmarest, 1817)

For synonymy see Henry (1970, 1980), Sadler (1974), Fortey and Morris (1982), and Hammann (1983). Fortey and Morris (1982, p. 70) attributed this species to Desmarest while Hammann (1983, p. 63) attributed it to 'Brongniart *in* Desmarest 1817'.

Neseuretus (*Neseuretus*) cf. *tristani* (Brongniart *in* Desmarest, 1817)

Plate 47, figs. 8–12

Material. Over fifty cephala, cranidia, and pygidia; internal and external moulds.

Horizon. From the base of Hanadir Shale and probably up to at least level of abundant *P. vacuvertis*, about 7 m from the top.

Discussion. As Fortey and Morris stated (1982, p. 72), this species has been revised recently (Henry 1970, 1980; Sadler 1974; and also Hammann 1983) and no further description is necessary. The minor differences noted by Fortey and Morris between the pygidium in their material and that described by Henry is partly substantiated in the present specimens where no more than eight axial rings have been observed but up to seven may be defined across the midpart of the axis. We are in agreement with Fortey and Morris that a specific distinction cannot be made on this character alone. However, despite the close similarity to *N.* (*N.*) *tristani* we only compare our material to that species since all our specimens consistently show more backwardly directed S2 glabellar furrows and never the transversely directed S2 typical of that species (see Henry 1970; Hammann 1983, etc.). Also the frontal border, although long, is not so steeply upturned as in *N.* (*N.*) *tristani*.

Hammann (1983) distinguished two subspecies of *N.* (*N.*) *tristani*: *tristani tristani* and *tristani tardus*. The differences between the two are slight (Hammann 1983, p. 69) and it was not possible to assign the present material to either of the subspecies with any certainty.

Family HOMALONOTIDAE Chapman, 1890
Subfamily KERFORNELLINAE Henry, 1980
Genus KERFORNELLA Henry, 1976

Type species. *Asphus brevicaudatus* Deslongchamps, 1825.

Kerfornella sp.

Plate 47, fig. 1

Material. H81. Internal mould of pygidium.

Horizon. Unknown but probably at level of *P. vacuvertis*; about 7 m below the top of the Hanadir Shale.

Description. Pygidium nearly twice as wide as long, although posterior margin poorly preserved. Anterior margin strongly and evenly curved. Anteriorly axis nearly half width of pygidium, narrowing evenly backwards to third axial ring, posterior to which there is a slight bulge. Axis delimited by well-marked furrows except at tip. Two anterior ring furrows best defined, except medianly where slightly forwardly flexed. Third furrow weak; fourth furrow barely present, marked by faint distal portions. Terminal piece about one-third length of axis. Pleural lobes with four pairs of furrows not reaching border, fourth pair very faint. Strong articulating furrow on axis continues into well-marked furrows on lobes which are truncated abaxially. Faint vincular furrow(?) present just posterior to pygidial axis. Pygidium gently convex (trans.); longitudinally the axis is most strongly curved posterior to the third axial ring furrow.

Discussion. The semi-circular outline, poorly defined axis posteriorly, and number of axial rings and pleurae agree well with the diagnosis of the genus given by Henry (1976, p. 666). Henry (1980, 1981) illustrated pygidia of four species of *Kerfornella* from north-western France. The specimen from the Hanadir Shale differs from *K. besnevillensis* (Bigot) and *K. morieri* (Bigot) in having fewer axial rings and a less well-defined posterior margin to the axis. *K. miloni* Henry conversely shows weaker axial ring furrows and pleural furrows. *K. brevicaudata* (Deslongchamps) possesses only one axial ring furrow, although Hammann (1983, p. 99) illustrates a pygidium with a weakly developed second furrow. *K. barrandei* (Hammann 1983) does not possess furrows on the pleural lobes and the axial furrows are straighter.

Genus PLAESIACOMIA Hawle and Corda, 1847

Type species. Plaesiacomia rara Hawle and Corda, 1847.

Plaesiacomia vacuvertis Thomas, 1977

Plate 47, figs. 3–5, 7

1977 *Plaesiacomia vacuvertis* sp. nov.; Thomas, pp. 164–168, pl. 23, figs. 6, 8–11; pl. 24, figs. 1–6.

Material. H60–H68 containing at least twenty-three cephala and cranidia, five pygidia and thoracic segments; preserved as internal and external moulds. H82 is an internal mould of an almost complete individual.

Horizon. Most of the specimens are probably from about 7 m below the top of the Hanadir Shale.

Discussion. This species was fully described and figured by Thomas (1977). Little need be added to Thomas's description except to note that in the adults examined in the present material a high proportion showed glabellar furrows, albeit weak; they were not absent as Thomas indicated. Some pygidia possess up to four axial rings which is more than Thomas observed in his material.

Plaesiacomia sp. aff. *Plaesiacomia rara* Hawle and Corda, 1847

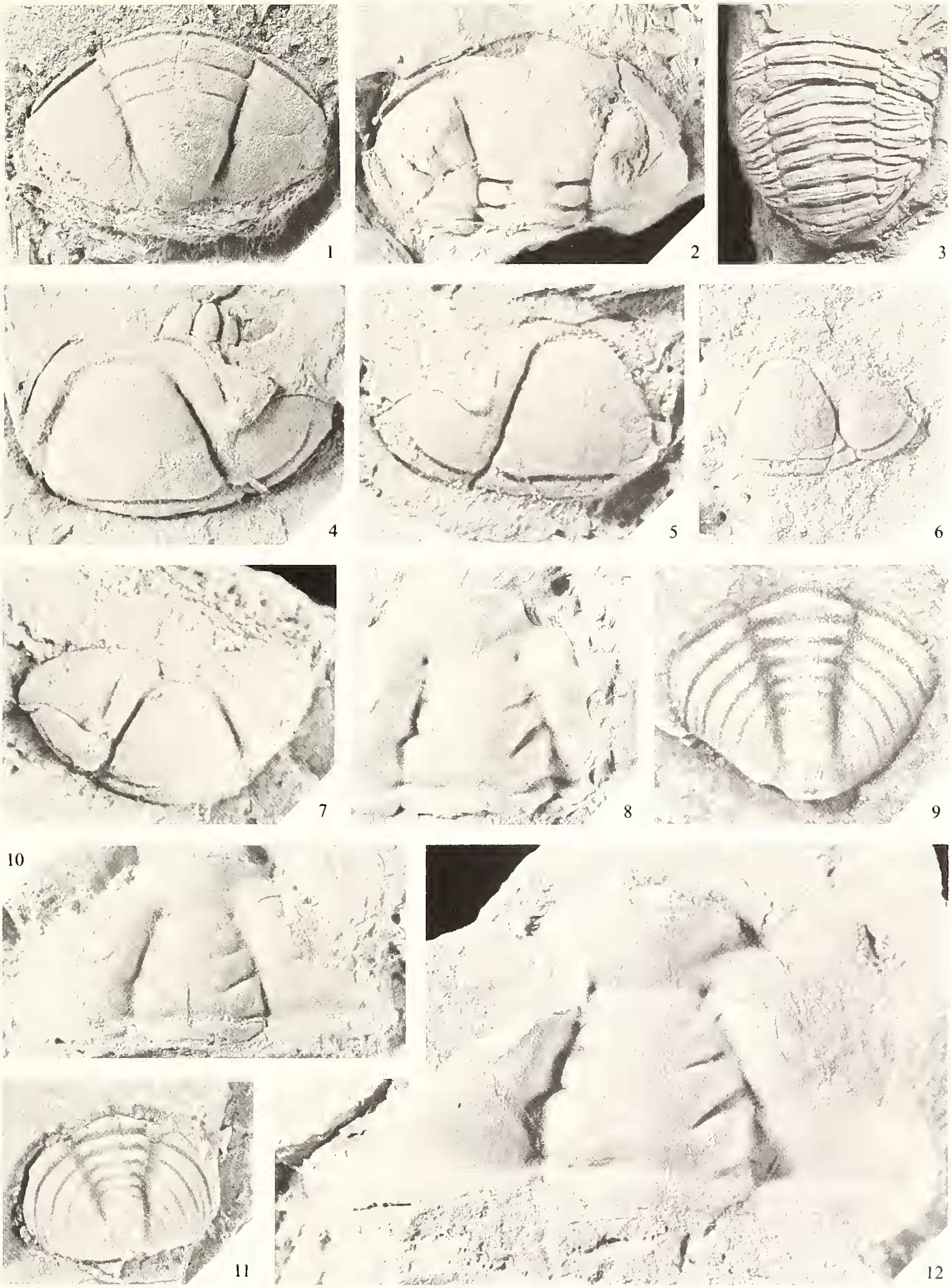
Plate 47, fig. 6

Material. H69/70. Part and counterpart of incomplete cranidium.

Horizon. Unknown but probably at level of *P. vacuvertis*; about 7 m below the top of the Hanadir Shale.

EXPLANATION OF PLATE 47

Fig. 1. *Kerfornella* sp. H81, × 3.
Fig. 2. *Kloucekia* sp. H71, × 3.
Figs. 3–5, 7. *Plaesiacomia vacuvertis* Thomas, 1977. 3, H66, × 4; 4, H68, × 4·5; 5, H62, × 5·5; 7, H64, × 6.
Fig. 6. *Plaesiacomia* sp. aff. *Plaesiacomia rara* Hawle and Corda, 1847. H69, × 6.
Figs. 8–12. *Neseuretus* (*Neseuretus*) cf. *tristani* (Brongniart *in* Desmarest, 1817). 8, H20, × 2; 9, H8, × 5; 10, H54, × 5; 11, H51, × 3; 12, H2, × 4.



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Description. Glabella slightly wider than long, anterior width just over one-quarter of posterior width. Glabella sides nearly straight except at posterior end where there is a flexure in axial furrow (paraglabellar area). Axial furrows deepest anterior to paraglabellar areas; along anterior margin of glabella, furrow widens slightly; median part of glabella indented on internal mould. Possible trace of basal glabellar furrows anterior to paraglabellar areas. Frontal area narrow, increasing slightly in width abaxially. Occipital ring of uniform width, well-marked occipital furrow. Postocular fixed cheeks wide, palpebral lobes situated well forward at about four-fifths length of glabella from posterior end. Preocular fixed cheeks narrow, outer margin parallel to margin of glabella. Posterior border furrows deep, shallowing abaxially.

Discussion. The cranidium differs from that of *P. vacuvertis* in having a narrower anterior width to the glabella, more even width (trans.) to the preocular fixed cheeks, and particularly in the considerably more forwardly placed palpebral lobes. Thus although the species is represented by only a single specimen it is clearly distinguishable from *P. vacuvertis*. It is, however, very similar to *P. rara* figured by Dean (1966, p. 133, pl. 1, figs. 1. 2. 7) from the Letna Formation (Caradoc) of Bohemia who remarked on the presence of faint glabellar furrows in one of Barrande's illustrations (Barrande 1852, pl. 29, fig. 21; see also Barrande 1872, pl. 5, fig. 27). The cranidium of *P.* n. sp. aff. *rara* (Henry 1980, p. 111, fig. 50; pl. 24, figs. 7, 9–11) from the Caradoc of Normandy is also very similar to the present material. Until a pygidium is known from Saudi Arabia we prefer to leave the nomenclature open.

Family DALMANITIDAE Vogdes, 1890
Subfamily ACASTINAE Delo, 1935
Genus KLOUCEKIA Delo, 1935

Type species. Phacops phillipsi Barrande, 1846.

Kloucekia sp.

Plate 47, fig. 2

Material. H60, H71. Internal moulds of cephalon.

Horizon. About 7 m below top of Hanadir Shale, associated with *Plaesiacomia vacuvertis* Thomas.

Description. Cephalon over half as long as wide, with rounded anterolateral margins, and slightly pointed anteriorly. Glabella reaches (?) anterior margin, sides converge as far back as basal furrows then run parallel. Axial furrows shallow. S1 short, directed inwards and slightly backwards, deep over most of length but shallow near axial furrow. L1 subrectangular in outline, but bulbous adaxially. S2 very faint, subparallel to S1, slightly curved forwards and not reaching axial furrow. S3 very faint, directed inwards and backwards at about 45° to axial furrow, barely discernible adaxially, terminating in shallow pit in axial furrow. Occipital ring delimited by deep occipital furrow behind L1. Median part of ring wider (sag.) where shallow occipital furrow is forwardly flexed. Eyes crescent-shaped in outline, running from just outside axial furrow behind shallow pit at end of S3 to level with extreme posterior part of L2. At least twenty-five vertical rows of eye lenses (preservation poor) showing hexagonal packing; up to six lenses per row. Anterior course of facial suture obscure; from eye it converges towards anterolateral margin of glabella. Behind eye, suture curves outwards and forwards, then backwards to lateral margin. Genal angles apparently rounded. Posterior border furrows wide, as deep as median part of occipital furrow, dying out at genal angles. Free cheek with faint border furrow. Cephalon with very low convexity longitudinally; transversely the lateral portions of the cephalon slope steeply outwards. Only ornament present is fine tuberculation on doublure.

Discussion. The deep S1, weak S2 terminating before the axial furrow, weak S3 and apparent absence of genal spines recall features seen in species of *Phacopidinia*, *Kloucekia*, and *Morgatia*. However, according to Hammann (1974, p. 96), *Morgatia* has large eyes reaching back to near the posterior border, bifurcating S1 at their inner ends, and S3 which join the axial furrows at right angles. None of these features is seen in the present specimen. With regard to the two former genera (see discussion in Henry 1980, pp. 123–127), the Arabian specimen does not show the typical outward curve of the axial furrow between S1 and S3, although in other characters the specimen has much in common with these two related genera. Dean (1961, p. 321) remarked that the only difference between the two genera is the mucronate pygidium of *Phacopidina*. Dr. J.-L. Henry, University of Rennes, kindly studied a photograph of specimen H71 (Pl. 47, fig. 2) and remarked that the apparent absence of a flat anterior border suggested that the specimen may be assigned to *Kloucekia* and in particular to *K. drevermanni drevermanni* (Hammann 1974, p. 80) from the Llanvirn of Spain. The Arabian specimens, although rather poorly preserved, differ from the Spanish species in having shorter (exsag.), more forwardly placed eyes and more inwardly directed S1 furrows. Until more material is available the specimens are provisionally referred to *Kloucekia* sp.

Family TRINUCLEIDAE Hawle and Corda, 1847
Subfamily HANCHUNGOLITHINAE Lu, 1963
Genus NINGKIANOLITHUS Lu, 1954

Type species. Cryptolithus welleri Endo, 1952.

Ningkianolithus hanadirensis sp. nov.

Text-fig. 3

Diagnosis. Ningkianolithus with radial rows of pits widely spaced and often irregular in front of glabella. Outer arcs of pits frontally and laterally only slightly larger than remainder. Up to six arcs of pits anterolaterally. Anterolateral margin of fringe geniculate, with short spine occasionally developed. Eye tubercle, eye ridge, and very faint genal caeca present. Genal spine in line with lateral margins of fringe.

Type material. Holotype, It 18820, internal mould of cephalon. Paratypes, It 18821–18825. It 18821, 18823, 18824, 18825, internal moulds of cephalon; It 18822, external mould of cephalon. Four other specimens housed in the Geology Department, King Saud University, Riyadh, Saudi Arabia (H25, 77, 78, 79).

Horizon and locality. Base of Hanadir Member, Tabuk Formation, immediately above junction with Saq Formation. Al Hanadir (26° 27′ 50″ N., 43° 27′ 20″ E.), about 53 km west-north-west of Buraydah, Al Qasīm Province, Saudi Arabia.

Derivation of name. After locality known as Al Hanadir where the specimens were found.

Description. Cephalon just over twice as wide as long, excluding genal spines, and ranging in length from 3·25 to 5·5 mm. Anterior margin forwardly flexed in front of glabella, slightly curved for much of cephalic width, then directed backwards and outwards through sharp angle where very short anteriorly directed spines are situated. Glabella expands forward, anterior margin gently curved, preglabellar field absent. At least two pairs of faint glabellar furrows present in posterior half of glabella, weakly defined alae. Axial furrows shallow with faint anterior fossula. Glabella with quite strong traverse convexity, highest part of glabella just anterior to midlength. Occipital ring short (sag.) and backwardly curved; occipital furrow shallow medianly, with well-marked lateral occipital pits. Cheeks gently convex, steeply declined laterally. Prominent eye tubercle situated about two-fifths the length (exsag.) of the cheek from posterior border and slightly nearer to axial furrow. Thin eye ridge runs inwards and slightly forwards from eye tubercle to axial furrow. Very faint genal caeca extends from posterolateral side of eye tubercle, curves backwards between posterior fossula and fringe, and cuts posterior border. Posterior border furrow wide near glabella, narrowing distally to posterior fossula. Posterior border narrow (exsag.), convex. Faint reticulation on glabella and cheeks, present on internal and external moulds (text-fig. 3*d*).

Fringe more or less flat anteriorly, lateral portions sloping gently outwards. Fringe narrow in front of glabella (constricted by frontal lobe of glabella), widening evenly to angulation, then of even width to posterior border. Marginal border broad, upturned anteriorly, widest at angulation. Genal spines at least three-quarters as long as glabella, directed backwards and slightly outwards, forming more or less straight line with lateral margin of fringe. Girder submarginal(?) (text-fig. 3*g*) on lower lamella, no trace of terrace lines. In the specimen where the pits are most regularly arranged (text-fig. 3*e*) the notation is as follows: I_1: 1–18 (with auxiliary pits between R15–16), radius O not developed; I_2: 5–18 (auxiliary pits between R7–8); I_3: 7–15, then irregular; I_4: 8–?13 (including a few irregular auxiliary pits); I_5: 10–12; I_n: 1–17 (then unclear), with auxiliary pits between R7–11. Radial arrangement fairly good on outermost three arcs posterior to about R8, and on I_4, I_5, I_n. A faint list is present between I_1 and I_2 from about R7 to R17, but dies out before genal angle. Pits are generally absent

TEXT-FIG. 3. *Ningkianolithus hanadirensis* sp. nov. *a*, holotype, It 18820. *b–g*, paratypes. *b*. It 18823; *c*. It 18821–18822; *d*. H79, internal mould; *e*. It 18825; *f*. H78, internal mould; *g*. It 18824. All ×5.

immediately in front of glabella although rarely I_n persists as the only arc (text-fig. 3*a*, *c*). Minor variations occur in pit numbers and degree of radial arrangement but the range considered is intraspecific. Generally the largest pits occur anteriorly and in the outermost three arcs anterolaterally; the smallest pits are posterior to about R5 in the innermost two or three arcs.

Discussion. The Arabian species cannot be closely compared to any described trinucleid species, although on balance the material is most like the later meraspid stages of *N. welleri* (Lu 1964, p. 299, fig. 2). *N. hanadirensis* differs from *N. welleri* of comparable size (Lu 1975, pl. XXXVII, figs. 5, 9) in having less swollen and more angular anterolateral margins to the fringe, and not possessing the enlarged marrolithid-like pits. Also the genal spines are directed outwards at their proximal ends. *N. honghuayuanensis* Chang (1964, pl. 6, fig. 4) also differs from *N. hanadirensis* in possessing an outer arc of enlarged pits, rounded and swollen anterolateral margins, and numerous, randomly disposed small pits on the rest of the fringe. *N. sichuanensis* Lee (1978, pl. 109, figs. 1–3) and *N. tongziensis* Yin (Yin and Lee 1978, pl. 184, fig. 9) both possess a large number of irregularly arranged pits on the lateral portions of the fringe.

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A. A. EL-KHAYAL

Department of Geology
King Saud University
Riyadh, Saudi Arabia

M. ROMANO

Department of Geology
University of Sheffield
Beaumont Building
Brookhill
Sheffield S3 7HF, England

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